Swine Manure Nutrient Utilization, Crop Year 2001

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Introduction

Manure is an important resource for meeting the nutrient needs of corn and soybeans grown in Iowa. Land application is the most widely accepted and best economic and agronomic use of manure. Concurrently, however, is the environmental concern when manure nitrogen (N) and phosphorus (P) is not adequately accounted for or utilized by crops. Use of manure as a crop nutrient source requires producer confidence in nutrient availability and maintenance of high crop yields. When that confidence is lacking, either because of unknown application rates or uncertain nutrient content and crop availability, additional nutrient applications are often made to ensure adequate soil fertility levels. Historically these additional applications are increased manure application rates or additions of fertilizer. This leads to over-application of crop nutrients, reduced profits, and potential for off-site movement and water quality degradation.

On a statewide basis, using 11,820,000 market hogs as an example, there is 88,650,000 lb crop available N and 95,151,000 lb available P as P_2O_5 produced per year (ISU Pm-1811 – 50% of manure nutrients recoverable and 50% crop available the first year of application). This is a conservative estimate and a large amount of N and P that must be managed well for good crop yield, improved profitability, proper soil resource management, and enhanced water quality.

The overall project goal is to expand our knowledge about manure (focus on liquid swine manure) N and P availability for corn and soybean production in Iowa and to cause change in manure management practices by crop and livestock farmers. This includes adoption of soil testing, manure nutrient analysis, equipment calibration, proper rate application, and following land application best-management practices (BMP's) – so that yearly applications of additional commercial fertilizer can be reduced when appropriate. Specific focus is to demonstrate liquid swine manure application calibration and rate selection, document manure N and P availability to crops, compare crop yield with manure compared to commercial fertilizer in order to alleviate producers' uncertainty concerning applying additional N and P after manure application, monitor soil and plant nutrient responses to manure application, and evaluate environmental soil tests on manured soils.

The project uses an integrated producer-demonstration-education approach, with coordinated efforts between producers, agronomic extension and research faculty and staff, field agency and extension specialists, and special project coordinators in a series of field demonstrations across Iowa. Information learned from field observation and data analysis will be highlighted at field days and will assist producers with adoption of economic manure and nutrient management practices. This project will also provide information for various manure and nutrient management information sources, educational materials, and education programs.

Objectives

Objectives include: 1) work directly with producers and custom applicators to implement field demonstrations and to calibrate manure application equipment or demonstrate state of the art application equipment – to document current application rates and calibration procedures and share with producers appropriate manure application rates based on their manure analysis, calibration, and tractor speed; 2) document crop productivity based on manure N and P nutrients and compare to fertilizer sources; 3) provide information transfer to additional producers, landowners, and custom applicators via on-farm demonstrations and field days (including demonstration awareness through field signage) and education programs; and 4) update manure management planning information such as nutrient availability and manure nutrient content as data warrants.

Field Demonstration Description

The strategy for this project is to conduct on-farm field demonstrations across Iowa with concurrent data collection to document liquid swine manure N and P availability to crops and compare crop yields with manure compared to commercial fertilizer. In the first two years of the project, twenty-three demonstration sites were established in nine counties. Swine manure was applied before corn and soybean crops, and at some sites second-year residual manure nutrient response was monitored.

Liquid Swine Manure Application at Story County (Story City) Demonstration Site on November 10, 2000.

There are several critical aspects to the demonstration work: 1) calibration of producer and custom applicator manure application equipment; 2) documenting manure analysis; 3) application of replicated manure rate strips across fields by producers or custom manure applicators; 4) placement of replicated fertilizer rates within each manure treatment strip; and 5) collecting soil and plant measurements to substantiate crop availability of manure N and P nutrients. These critical components are required to provide the necessary data and education to move manure management to the desired goal of a recognized and valued nutrient resource – one treated like a fertilizer nutrient source.

Following is an abbreviated listing of the field work plan for the demonstrations: 1) manure application equipment with expected capability to apply agronomic rates and producer willingness to calibrate the manure applicator, or availability of a calibrated commercial manure applicator with electronic flow control equipment; 2) compilation of a production, crop rotation, nutrient application, and soil test history of each field; 3) manure records, pre-application sampling and analysis to set application rates; 4) working with producers, make manure and nutrient applications to the demonstration sites: (a) replicated manure rate strips, including a control with no manure, and (b) replicated fertilizer N and P rates applied to small areas within each manure application strip; 5) collect samples for routine soil and environmental N and P tests, plant N and P tests, grain yield, and color aerial images; and 6) study residual manure effects to the next crop in rotation.

Project Activity

Major activities are identification of project cooperators, location of field demonstration sites, pre-application manure sampling, soil sampling, liquid swine manure application, manure sampling, fertilizer application, and grain harvest.

2000 Sites

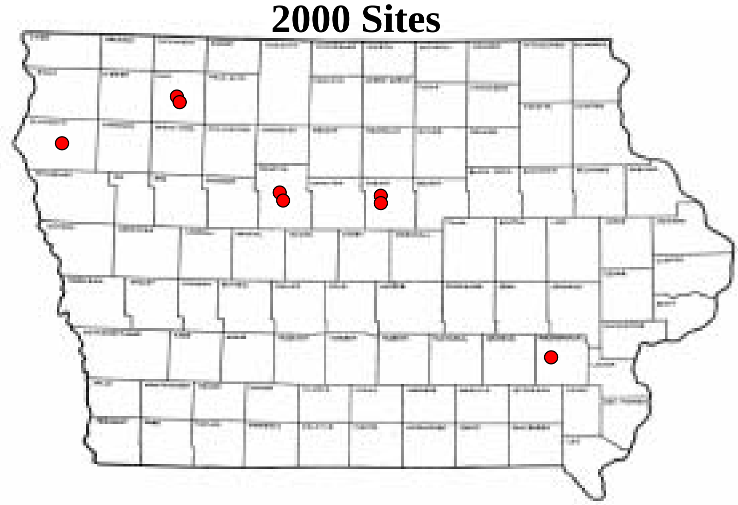

Figure 1. Swine Manure Nutrient Utilization Demonstration Sites, 2000.

Eight demonstration sites were utilized in 2000 (Figure 1), and fifteen in 2001 (Figure 2). All sites utilized liquid swine manure. Manure at each site was from under-building pit storage, with the exception of one site with outdoor concrete tank storage. Some sites had manure applied in the fall (Floyd County and Washington County), with the rest of the sites in 2000 and 2001 applied in the spring. Four sites in 2001 utilized residual manure nutrients from spring 2000 applications. The rapid closure of the fall 2000 application season (time period after soil cooling) resulted in many sites moving to spring application. Wet soil conditions in the spring 2001 delayed some manure applications and planting and placed two sites at risk because of excessively wet conditions after planting.

2001 Sites

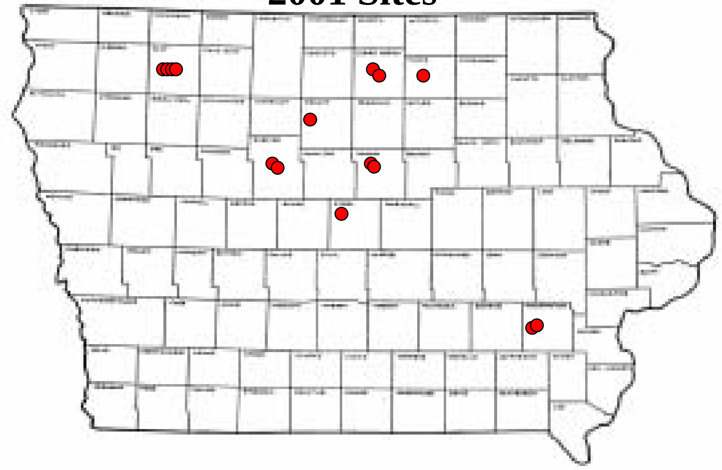

Figure 2. Swine Manure Nutrient Utilization Project Demonstration Sites, 2001.

Manure application equipment was calibrated at application. At some locations applicators were equipped with an electronic flow monitor and rate controller, which aided application and rate uniformity. Manure was surface broadcast applied with immediate incorporation at the Clay county sites, and injected at all other sites. Multiple manure samples are collected during application. These are analyzed for total N, ammonium, total P, total potassium (K), and solids. At each site cooperators are asked to not apply manure or fertilizer to the site area, other than manure strips. All other field activities are completed as normal by the cooperator, including grain harvest of the application strips.

Manure Demonstration Rates and Fertilizer Applications for Corn

Three manure application strips across the field length (replicated three times): check – with no manure, fertilizer N, or fertilizer P; half – manure at rate to supply approximately half corn N need (75 lb total N/acre); and full – manure at rate to supply approximately full corn N need (150 lb total N/acre). These rates are for corn following soybean and are intended to supply adequate manure-N and less-than-adequate manure-N. The assumption is made that all of the swine manure N is first-year crop available. The individual manure strip widths match a multiple of the combine header width.

Fertilizer N application is hand applied to small plots within each manure application strip: superimpose four randomized small plot fertilizer N rates on each manure and control strip: 0, 40, 80, 120 lb N/acre (Figure 3). These are applied by hand to the soil surface in the spring immediately after corn planting. The N source is ammonium nitrate. A blanket application of P (60 lb P_2O_5/acre) and K (60 lb K_2O/acre) fertilizer is made to the small N plots in order to mask the effect of these nutrients applied in the manure.

Fertilizer P application is hand applied to small plots within each manure application strip (usually only at those sites with optimum to very low soil P tests): superimpose four randomized fertilizer P rates on each manure and control strip: 0, 20, 40, 60 lb P_2O_5/acre. These are broadcast applied by hand and incorporated with secondary tillage. The P source is triple superphosphate. A blanket application of N (100 lb N/acre) and K (60 lb K_2O/acre) fertilizer is made to the small P plots in order to mask the effect of these nutrients applied in the manure.

At some sites manure rates were based on intended P application or other intended N rates. For example, at a continuous corn site, rates might be at 100 and 200 lb total N/acre.

View of Field-Length Replicated Treated and Untreated Strips at the 2001 Wright County (Dows) Demonstration Site.

Manure Demonstration Rates and Fertilizer Applications for Soybeans

Three manure application strips across the field length (replicated three times): check – with no manure, fertilizer N, or fertilizer P; half – manure at rate to supply approximately half soybean grain N removal (100 lb total N/acre); and full – manure at rate to supply approximately full soybean grain N removal (200 lb total N/acre). The assumption is made that all of the swine manure N is first-year crop available. The individual manure strip widths match a multiple of the combine header width.

Fertilizer P application is hand applied to small plots within each manure application strip: superimpose four randomized fertilizer P rates on each manure and control strip: 0, 20, 40, 60 lb P_2O_5/acre. These are broadcast applied by hand and incorporated with secondary tillage. The P source is triple superphosphate. A blanket application of K (60 lb K_2O/acre) fertilizer is made to the small P plots in order to mask the effect of this nutrient applied in the manure.

Soil and Plant Sampling

The overall project soil and plant sampling and analyses includes the following: collect spring soil samples, sample small corn and soybean plants and determine plant weight and P content, collect late spring nitrate test and other soil N test samples, take Minolta SPAD chlorophyll meter readings from corn ear leaves at the R1 growth stage (silking stage) to monitor N response through leaf greenness, harvest manure strips and small plots for grain yield, collect end-of-season cornstalk samples, fall soil samples, and post-harvest profile soil nitrate samples, and analyze soil samples for routine soil tests, soil N tests, and environmental P tests.

Grain yield is determined for each manure strip by combine harvest and for each small N and P fertilizer small plot by hand harvest of measured areas, with yields adjusted to 15.5% grain moisture. Seed protein, oil, and starch are determined by near-infrared spectroscopy (NIR) analysis.

As of this reporting date, not all soil and plant analyses have been completed and therefore are not reported.

Preliminary 2000 and 2001 Results

Field Manure Application (Calibration and Sampling)

An important component of the demonstration project is increasing producer awareness of the importance of manure sampling to estimate total nutrient content. At all 2000 and 2001 demonstration sites pre-application manure samples were collected for determination of total N or total P_2O_5/1000 gallons manure; once determined, the total N or P nutrient concentrations were used to calculate agronomic manure application rates for each demonstration site (Table 1 and Table 2). The results of pre-sampling and sampling during application highlight the consistency of manure total nutrient concentrations within a single manure source, and the ability of the pre-sampling to successfully guide application rates. Manure nutrient concentrations varied considerably between sites, indicating the need for manure analysis history and pre-application sample analysis, and indicating the improvement in setting application rates with actual analyses instead of using tabled (book) values. In conjunction with applicator calibration (through use of weigh pads and application over known areas), intended rates were achieved with good consistency.

Yield and Associated Plant Growth Measurement Response to Swine Manure and N Fertilizer

Preliminary data suggest that corn yield level and yield response to manure and supplemental N fertilizer varied between sites in 2000 (Table 3). Half- and full-rate manure applications increased average corn strip yields relative to check treatments at three of five sites. At the sites responding to manure, the half-rate of manure appeared to supply adequate to near-adequate plant-available N. The full manure rate only increased yields further when more N was needed than supplied by the half rate (example is the Clay County site). As expected, measurements of late-spring soil nitrate-N, VT stage corn ear leaf greenness, and post-harvest soil nitrate-N generally increased with manure application at most sites. Generally, when manure N or manure plus fertilizer N application was greater than corn need, soil and stalk nitrate tests indicated high levels, especially when the N rate was excessive. SPAD readings and leaf chlorophyll (leaf greenness) will not indicate excess N, but will show deficiency; therefore, those readings do not increase once maximum greenness is reached, even with more N.

Superimposed small-plot corn yield response to supplemental N fertilizer was most consistent in check and half-rate manure strips. At only the most N-responsive sites did corn yield increase with additional fertilizer N applied on top of the half-rate manure application, and with only up to 40 lb fertilizer N/acre. In those instances, the amount of manure total N applied with the half-rate plus the additional fertilizer N approximated the amount of fertilizer N required to achieve full yield on the control (no manure) strips. At no site in 2000 was there additional yield increase from fertilizer N on top of the full-rate manure application. First-year yield data suggest that supplementing swine manure application with additional fertilizer N is not a requirement. A consistent, economical yield response will occur only when the manure application does not supply enough N to meet corn N needs at responsive sites (example is with the half-rate at some sites in this project). In addition, these data suggest that the N in liquid swine manure is highly available to corn in the year of application and appears to support the current suggestion that first-year swine manure N availability is approximately 100 percent.

Yield and Associated Plant Growth Measurement Response to Swine Manure and P Fertilizer

Effects of supplemental P fertilizer on corn yield were tested at only one location (Webster County) in 2000. Preliminary soil sampling of small-plot areas indicated “optimum” Bray-1 soil P test levels. Results from this site support ISU fertilizer and manure P recommendations--additional P applied in the form of manure and supplemental P fertilizer may increase early-season corn growth, but seldom increase grain yield (Table 3) when soil test levels are optimum and higher.

Late-summer Aerial Photo of Replicated Manure Strips in Corn at the 2000 Webster County (Fort Dodge) Demonstration Site.

Effects of manure and supplemental P fertilizer on soybean yield were tested at three locations in 2000. Results from the Clay and Webster County "manure application before soybean" sites concur with results from other recent studies showing small soybean yield and growth response to manure—even when Bray-1 soil P test levels are high. The soybean yield response in high-testing soils was not observed when fertilizer P was applied, also concurring with previous research. The observed yield response to manure is most likely due to complex, poorly-understood nutritional and physical factors influenced by manure application (not the manure P itself). Post-harvest soil profile nitrate generally did not indicate increased concentrations with application to soybean.

Swine Manure Effect on Soil P as Measured by Agronomic and Environmental Tests

A component of the demonstration is to evaluate the performance of new environmental soil P tests. Preliminary results summarized in Figure 4 suggest that the three agronomic soil P tests (Bray-1, Olsen, and Mehlich-3 methods) and the two environmental soil P tests (Iron oxide and water extraction methods) provided similar estimates of manure application effects on post-harvest soil-test P levels. As expected, low manure rates generally produced little change in post-harvest soil-test P levels (as measured by all tests). The tests extracted widely different amounts of P from post-harvest soil samples. Full manure rates increased post-harvest soil-test P levels of all tests. Increases in soil test P provide an indication of the high crop availability of P in liquid swine manure.

Preliminary data shown in Figure 5 suggest that although all five P tests extracted different amounts of P, the amounts extracted were highly correlated across agronomic and environmental P tests. The trend lines also reveal no difference in soil P test performance between check and manure-treated soils other than the soil P level. The water extraction environmental soil P test appears to follow the same trends as other tests; however, the test extracts so little P that it may be more susceptible to sampling and laboratory error than the other tests, potentially making the water test less useful to detect increases in soil P resulting from manure application.

Preliminary results suggest that all soil P tests will adequately evaluate the impact of swine manure on soil P (once amounts of P extracted are considered through appropriate field calibrations). Previous research showed that the agronomic soil P tests are better correlated to yield response from soil nutrient additions. Producers are advised to use the currently-used routine soil tests (Bray-1, Olsen, Mehlich-3) for both agronomic and environmental assessments of the impact of manure on soil P. These conclusions are based on one year of preliminary data; data from year two of the project is being analyzed to substantiate these preliminary conclusions.

Project Success in 2000 and 2001

Generally the project has achieved its objectives and exceeded expectations in 2000 and 2001. The number of demonstration sites has increased each year of the project, a trend that is expected to continue for 2002. The greatest challenge facing the project is identifying P responsive sites, although recent efforts have been successful in locating three sites for 2002 where initial soil test P results are low enough to predict responsiveness to P treatments. Problems identified during establishment (inability to apply low enough rates) and results of the field demonstration at our 2000 Plymouth County site convinced that cooperator to modify his existing manure application strategies by better monitoring total nutrient levels and discontinuing use of his existing manure applicator. Another project success is increased custom applicator awareness of the need for consistent application rate, with greater interest in equipping applicators with flow-rate controllers.

Vacuum Tank-Style Liquid Manure Application Applying Treatment Strips at the 2000 Plymouth County (LeMars) Demonstration Site.

Education Component and Outreach Activity

The following outreach activities occurred at the project sites in 2000 and 2001. Field signs indicating the project name, program, and cooperating organizations were located at many sites. Education activities will accelerate as the project develops and results are summarized across more years. When the 2001 demonstration results are completed and summarized, project participants and local coordinators will be asked to meet and discuss the results. Information gained from the project will be delivered to farmers, agbusiness, and agency personnel through meetings, conferences, on-going extension education programs and certification programs, fact sheets, newsletters, and web materials.

Project personnel with example demonstration signage at Webster County Educational Field Day September 13, 2001. Pictured are the following persons. (Front) project graduate student Sudipta Rakshit; (Back, L-R) Paul Miller (NRCS), Elaine Ilvess (IDALS), Dr. John Sawyer, and Jim Patton (Webster Co. CEED).

An important educational multiplier is the extensive use of the project information in extension programs and manure confinement site and custom manure certification programs. From January to March, 2001 results of this project were an integrated educational section of the "Nutrient Value of Liquid Manure" component of the statewide confinement site manure applicator certification meetings. Nine hundred sixty-eight certified confinement site manure applicators learned about this on-going field demonstration project and the results at seventy-seven certification meetings. Project coordinators made presentations integrating results of this project to over six hundred people at ten Extension and agribusiness meetings in 2000 and 2001. Additional outreach and promotion of the project occurs as results are summarized and reported in various popular press articles and through radio interviews. An example is the fall 2001 Soybean Digest article "Liquid Gold - Understanding and Utilizing Swine Manure", which highlighted activities and results of the project.

2000 and 2001 Field Days

In cooperation with producers, site cooperators, community colleges, and Iowa Department of Agriculture and Land Stewardship and Iowa State University Extension staff, multiple field days were conducted in the summer of 2000 and 2001 at the demonstration sites. Local crop farmers, swine producers, dealers, certified crop advisors (CCA's), and the general public attended the field days and viewed the demonstration sites.

Following is a listing of the field day activities.

Hardin County – July 27, 2000
Washington County – August 9, 2000
Clay County – August 31, 2000
Webster County – September 12, 2000
Wright County – June 1, 2001
Wright County – July 9, 2001
Cerro Gordo County – August 1, 2001
Hardin County – August 2, 2001
Clay County – August 31, 2001
Webster County – September 13, 2001
Wright County – September 19, 2001

Additional Education Components

An important component of this project is to document the process of applying agronomic-based liquid swine manure application rates – especially a method that can successfully result in the application of desired nutrient rates. For most corn production fields and for requirements of the Department of Natural Resources manure management plans, the rate is based on corn N needs. Once the rate of N to be applied is determined for a particular field, the manure rate is calculated from that N need. This project is documenting that it is possible to accurately set those rates and to accurately achieve application of those rates in the field. It takes effort and proper equipment, but it is possible. The process utilized in the project is this. First, a presample of the liquid manure is collected ahead of manure application. This sample is collected by dipping manure off the top of the manure in the storage (only if total N is determined), or probing the depth of the storage volume. The sample is collected far enough in advance of planned application for chemical analysis by a laboratory. The results for total N are compared to historical analyses from the structure to confirm nutrient content. Having a history of analyses is important to confirm current sample results. The presample total-N content is used to set the manure applications for the planned demonstration rates. Once the rate is determined, the applicator is calibrated before application, or a calibrated flow controller is utilized. Once calibrated, the manure rates are applied to the demonstration area. As the manure is applied, multiple manure samples are collected and sent to the lab for chemical analysis. The results of these samples are compared to the pre-sample and for determination of actual applied nutrient rates, and to develop a manure analysis history. In the two years of this project, when this process is followed carefully, the intended nutrient rate is accurately achieved.

At-application Manure Sample Collection for Nutrient Analysis.

A concern identified during this project is the inability of some application equipment (either applicator rate constraints or tractor size) to apply rates low enough for the intended project rates or to meet N rates required in a manure management plan. This issue could be addressed through assistance to producers for purchase of improved application technology such as driven pumps and especially liquid flow controllers and rate adjusting valves. Through the calibration component of this project, this type of application technology has been shown to accurately apply liquid manure at desired rates. Through this project and educational activities throughout the state, we are convincing producers of the value of liquid swine manure as a nutrient resource and improving the understanding of manure nutrient availability. However, the next step is to improve the capability of producers to apply liquid swine manure at planned agronomic rates.

A success demonstrated in this project has been the application of manure from area swine producers to cooperating crop producer sites (farmers that are not swine producers). This has occurred at multiple demonstration sites in the project and is an important aspect of improved interaction between livestock and crop producers, demonstration and acceptance of manure as a nutrient resource by crop producers, and recognition of the high crop nutrient availability and nutrient value of swine manure. This recognition has important implications for best manure utilization as application to land controlled by crop producers helps with manure management plans, provides improved manure distribution within a geographic area, relieves the pressure on swine producers to apply manure to land that doesn't need additional P, and gets the manure applied to land where crops can best utilize the nutrients.

Expected Benefits

One, producer recognition of the demonstration project and importance of manure nutrient management as a result of visibility through field signage and field days; two, multiple cooperating and neighboring producers adopt manure application calibration, manure analysis, and manure nutrient BMP's as a direct result of their participation in the project; and three, enhanced and refined information for manure management plan development and implementation by producers and custom manure applicators across Iowa.

Several project outputs are expected: 1) increased awareness of demonstration activities that reinforce the economic and environmental importance of manure nutrient management; 2) expanded statewide database of plant, soil, and crop yield response to applied swine manure and estimate of manure N and P availability; 3) improved interpretation of N and P soil tests in manured soils from both agronomic and environmental perspectives that will increase producer confidence in accepting manure as a reliable crop nutrient resource; 4) through a strong producer-field specialist-agbusiness-agency cooperative practice demonstration program, extensive outreach information transfer mechanism to producers and agbusiness via field days and meetings, promotion of experiences learned through the demonstrations, and use of information learned for manure management educational literature; and 5) improved understanding of the importance of manure nutrients in the planning and writing of nutrient plans.

Project Partners:

Crop and Livestock Producers
Heartland Pork
Iowa State University
Iowa State University Extension
Iowa Natural Resources Conservation Service
Iowa Department of Natural Resources
Division of Soil Conservation, Iowa Department of Agriculture and Land Stewardship
Leopold Center for Sustainable Agriculture
Iowa Central Community College

Figure 3. Example Demonstration Plot Layout, with Replicated Small N and P Fertilizer Plot Locations Superimposed on Replicated Manure Treatment Strips.

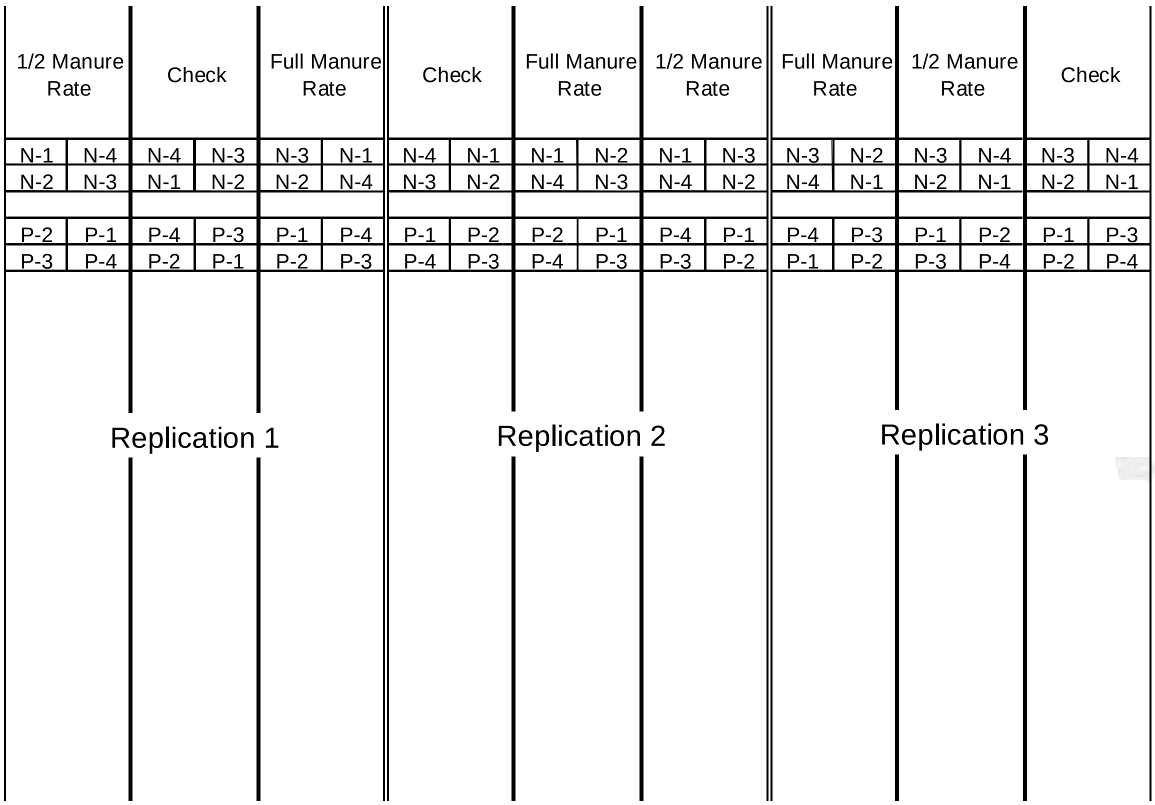

Figure 4. Effect of Swine Manure Application Rate on Post-harvest Residual Soil P as Measured by Five Soil Tests.

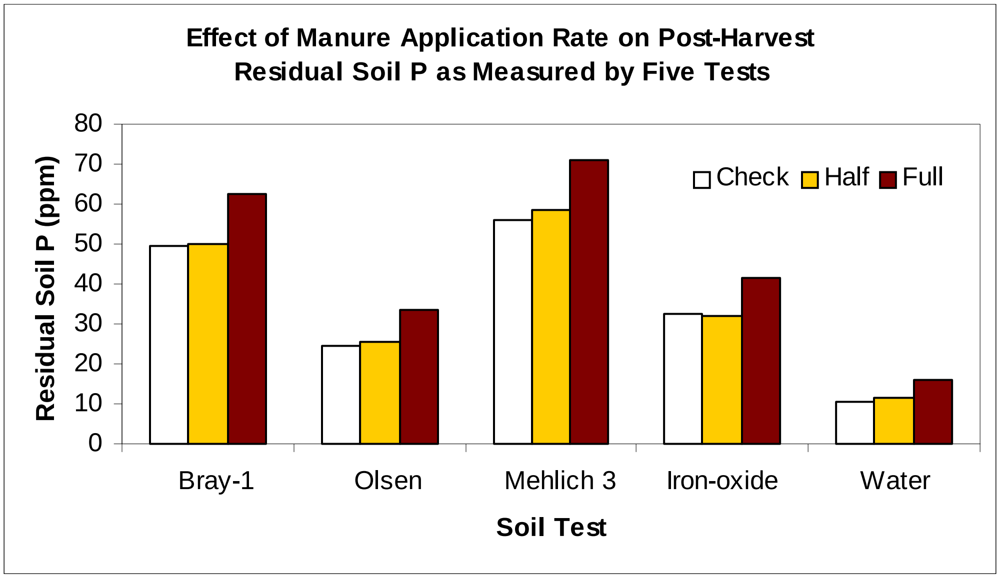

Figure 5. Correlations Between Soil P Tests for Manured and Unmanured Soils.